Active Deformation and Earthquake Potential of the Southern Los Angeles Basin, Orange County, California

External Grant Award No. 01HQGR0117

Lisa B. Grant, P.I., with Eric E. Runnerstrom and Eldon M. Gath
Dept. Environmental Analysis & Design, University of California, Irvine, CA 92697-7070;
phone (949) 824-5491 fax (949) 824-2056 email lgrant@uci.edu

NEHRP Element: III
Keywords: Tectonic geomorphology, Tectonic structures, Regional modeling, Surface deformation

Investigations Undertaken

The southern Los Angeles (LA) basin (shown in **Figure 1**) has been characterized as moderate to low seismic risk (Petersen and Wesnousky, 1994; WGCEP, 1995). This optimistic assessment is based on minimal knowledge of the neotectonics, and may be the result of a gap in knowledge rather than a lack of earthquake sources. Preliminary work suggests that several late Quaternary structures in the southern LA basin have significant rates of deformation but are poorly understood or unrecognized by seismic mitigation professionals and scientists. The earthquake potential posed by these structures is potentially disastrous for the nearly three million people who live and work in Orange County. We are addressing this knowledge gap by building on our recent work in the San Joaquin Hills (Grant et al., 1999; 2000; 2002) and Puente Hills (Gath, 1997) to identify and analyze other actively deforming structures in the southern LA basin.

We are conducting a quantitative tectonic geomorphologic analysis of the Santa Ana Mountains and foothills, with emphasis on the northern region of the Peralta Hills and Loma Ridge. The pattern of stream development and channel response is one of the most sensitive indicators of active tectonic deformation. Using standard geomorphic tools and techniques listed in **Table 1**, we are beginning to quantitatively analyze the fluvial system to determine how active deformation has affected its pattern of development. Much of this analysis is being accomplished with GIS, using a combination of ArcView, Spatial Analyst and RiverTools software processing of 10 m and 30 m DEM data.

Table 1: Tectonic geomorphic analysis methods, southern margin LA basin

• channel length, drainage basin area, and stream power (Hack, 1973; Ohmori, 1993) • marine and fluvial terrace morphology (Rockwell et al., 1984; Nicol et al., 1994; Rosenbloom and Anderson, 1994) • long river profiles (Personius, 1993; Merritts et al., 1994)	• stream channel deflections (Sieh and Jahns, 1984; McGill and Sieh, 1991) • topographic envelope, subenvelope, and residual maps (Bullard and Lettis, 1993; Bürgmann et al., 1994) • valley asymmetry (Cox 1994) • valley incision (Montgomery, 1994)

Results

To date, we have developed a GIS 3-D model of the study area, defined drainage basins for analysis (**Figure 1**), and imported the 1:48,000 scale digital geologic map of Orange County (Morton and Miller, 1981) for examining the effect of bedrock on geomorphology (not shown). The geologic units beneath the major drainages are primarily Tertiary sedimentary rocks.

Previous analysis of the Puente Hills (Gath, 1997) indicates that the varying bedrock lithologies have negligible impact on the development pattern of the fluvial system. We will evaluate the impact of bedrock units, but our initial hypothesis is that the rock units are sufficiently similar that they have minimal impact on drainage growth in much of the study area.

In this project we are looking for first-order deformation signals from previously unmapped active structures, possibly including blind faults. Blind faults do not have surface rupture expression, and hence cannot be studied by traditional paleoseismic trenching methods. Surface expression of blind structures may exist though, as a series of uplifting anticlinal hills and subsiding synclinal basins. There is a physical linkage between the rate of subsurface fault slip and the rate of landscape evolution in a process-response relationship. This relationship can be explored through geomorphic methods to yield kinematic and temporal data within the critical middle to late Quaternary time frame. In particular, the evolutionary pattern of a fluvial drainage system is highly sensitive to active tectonic processes (Schumm, 1986;). The streams have a predictable and measurable response to the neotectonic tilting, folding, and faulting of the ground surface.

The Santa Ana Mountains are a topographically prominent feature, extending to over 5600 ft elevation at Santiago Peak. Youthful topography and preliminary analysis of fluvial systems in the southern LA basin suggest that the Santa Ana Mountains are uplifting and may be tectonically active. Preliminary results indicate that tectonic tilting is discernable in the development pattern of fluvial networks. **Figures 1, 2 and 3** show strong asymmetry in the drainage basins for San Juan Creek in the southern Santa Ana Mountains (Fig. 1), and Santiago Creek in the northern Santa Ana Mountains (Fig. 1, 2 and 3). Santiago Creek flows northwestward between Loma Ridge to the southwest, the Santa Ana Mountains to the northeast, and the Peralta Hills to the north. The asymmetric drainage pattern suggests uplift of the Santa Ana Mountains and tilting to the southwest. Drainage basins on the slopes of Loma Ridge (not shown on Fig.3) are small, suggesting a youthful drainage system that may be developing in response to uplift of Loma Ridge.

We hypothesize that uplift of the Santa Ana Mountains (and possibly Loma Ridge and the Peralta Hills) is occurring in response to termination of the Elsinore fault and consumption of some of its strain into uplift. The Elsinore fault's 6 m/ky strain is partially transferred to the Whittier fault (2-3 m/ky) (Gath et al., 1992), and the Chino fault (~1-2 m/ky; Gath and Walls, 1999 SCEC Poster Session). The apparent strain deficit (1-3 m/ky) may be causing active uplift of the Santa Ana Mountains.

REFERENCES

Bullard, T.F. and Lettis, W.R., 1993, Quaternary fold deformation associated with blind thrust faulting, Los Angeles basin, California; Journal of Geophysical Research, v. 98, n. B5, p. 8349-8369.

Bürgmann, R., Arrowsmith, R., and Dimitru, T., 1994, Rise and fall of the southern Santa Cruz Mountains, California, from fission tracks, geomorphology, and geodesy; J. of Geophysical Research, v. 99, n. B10, p. 20,181-20,202.

Cox, R.T., 1994, Analysis of drainage basin symmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: An example from the Mississippi Embayment; Geological Society of America Bulletin, v. 106, p. 571-581.

Gath, E.M., 1997, Tectonic geomorphology of the eastern Los Angeles Basin; USGS Final Technical Report, NEHRP Contract No. 1434-95-G-2526, 13 p., 1 plate, 6 figures, 6 tables.

Gath, E.M., Gonzalez, T., and Rockwell, T.K., 1992, Evaluation of the late Quaternary rate of slip, Whittier fault, southern California; USGS Final Technical Report, NEHRP Contract No. 14-08-0001-G1696, 24 p., numerous plates.

Grant, L.B., Mueller, K.J., Gath, E.M., Cheng, H., Edwards, R.L., Munro, R., and Kennedy, G.L., 1999, Late

Quaternary uplift and earthquake potential of the San Joaquin Hills, southern Los Angeles basin, California; Geology, v.27, p. 1031-1034.
Grant, L. B., K. L. Mueller, E. M. Gath and R. Munro, 2000, Late Quaternary uplift and earthquake potential of the San Joaquin Hills, southern Los Angeles basin, California – REPLY, Geology, v. 28 (4), p.384.
Grant, L. B., L. J. Ballenger and E. E. Runnerstrom, 2002, Coastal uplift of the San Joaquin Hills, Southern Los Angeles basin, California, by a large earthquake since 1635 A.D., Seismological Society of America Bulletin, in press.
Hack, J.T., 1973, Stream-profile analysis and stream-gradient index; U.S. Geological Survey Journal of Research, v. 1, p. 421-429.
McGill, S.F. and Sieh, K., 1991, Surficial offsets on the central and eastern Garlock fault associated with prehistoric earthquakes; Journal of Geophysical Research, v. 96, n. B13, p. 21,597-21,621.
Merritts, D.J., Vincent, K.R., and Wohl, E.E., 1994, Long river profiles, tectonism, and eustasy: A guide to interpreting fluvial terraces; Journal of Geophysical Research, v. 99, n. B7, p. 14,031-14,050.
Montgomery, D.R., 1994, Valley incision and the uplift of mountain peaks; Journal of Geophysical Research, v. 99, p. 13,913-13,921.
Morton, P.K. and Miller, R.V., 1981, Geologic map of Orange County, California showing locations of mines and mineral deposits: California Division of Mines and Geology Bulletin 204, 1:48,000.
Nicol, A., Alloway, B., and Tonkin, P., 1994, Rates of deformation, uplift, and landscape development associated with active folding in the Waipara area of North Canterbury, New Zealand; Tectonics, v. 13, p. 1327-1344.
Ohmori, H., 1993, Changes in the hypsometric curve through mountain building resulting from concurrent tectonics and denudation; Geomorphology, v. 8, p. 263-277.
Personius, S.F, 1993, Age and origin of fluvial terraces in the central Coast Range, western Oregon; U.S. Geological Survey Bulletin 2038, 56 p.
Petersen, M.D. and Wesnousky, S.G., 1994, Fault slip rates and earthquake histories for active faults in southern California; Seismological Society of America Bulletin, v. 84, p. 1608-1649.
Rockwell, T.K., Keller, E.A., Clark, M.N., and Johnson, D.L., 1984, Chronology and rates of faulting of Ventura River terraces, California; Geological Society of America Bulletin, v. 95, p. 1466-1474.
Rockwell, T.K., Gath, E.M., and Gonzalez, T., 1992, Sense and rate of slip on the Whittier fault zone, eastern Los Angeles basin, California; in Stout, M.L. (ed), Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, p. 679.
Rosenbloom, N.A. and Anderson, R.S., 1994, Hillslope and channel evolution in a marine terraced landscape, Santa Cruz, California; Journal of Geophysical Research, v. 99, p. 14,013-14,029.
Schumm, S.A., 1986, Alluvial river response to active tectonics, in Studies in National Research Council (eds), Active Tectonics; National Academy Press, Studies in Geophysics, Washington, D.C., p. 80-94.
Sieh, K.E. and Jahns, R.H., 1984, Holocene activity of the San Andreas fault at Wallace Creek, California; Geological Society of America Bulletin, v. 95, p. 883-896.
Working Group on California Earthquake Probabilities (WGCEP), 1995, Seismic hazards in southern California: probable earthquakes, 1994 to 2024; Seismological Society of America Bulletin, v. 85, p. 379-439.

Reports published

This project summary is the first report prepared on this research.

Availability of data

Preliminary data is posted on the web at http://geolab.seweb.uci.edu/. Results will be posted as the project proceeds. Questions may be directed to the website email address, geolab@uci.edu, or to project personnel Lisa Grant (lgrant@uci.edu), Eric Runnerstrom (erunners@uci.edu) or Eldon Gath (egath@earthconsultants.com).

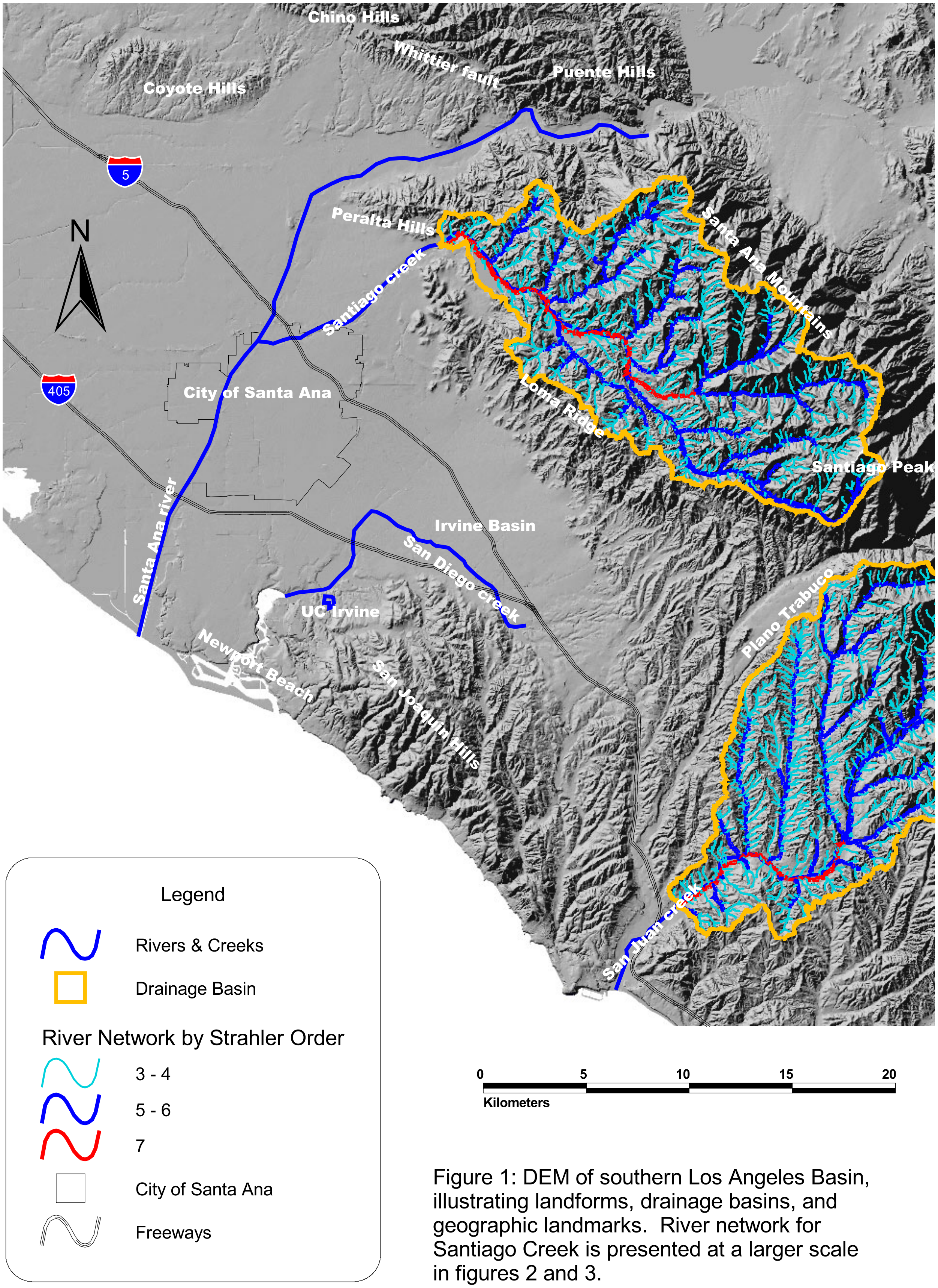

Figure 1: DEM of southern Los Angeles Basin, illustrating landforms, drainage basins, and geographic landmarks. River network for Santiago Creek is presented at a larger scale in figures 2 and 3.

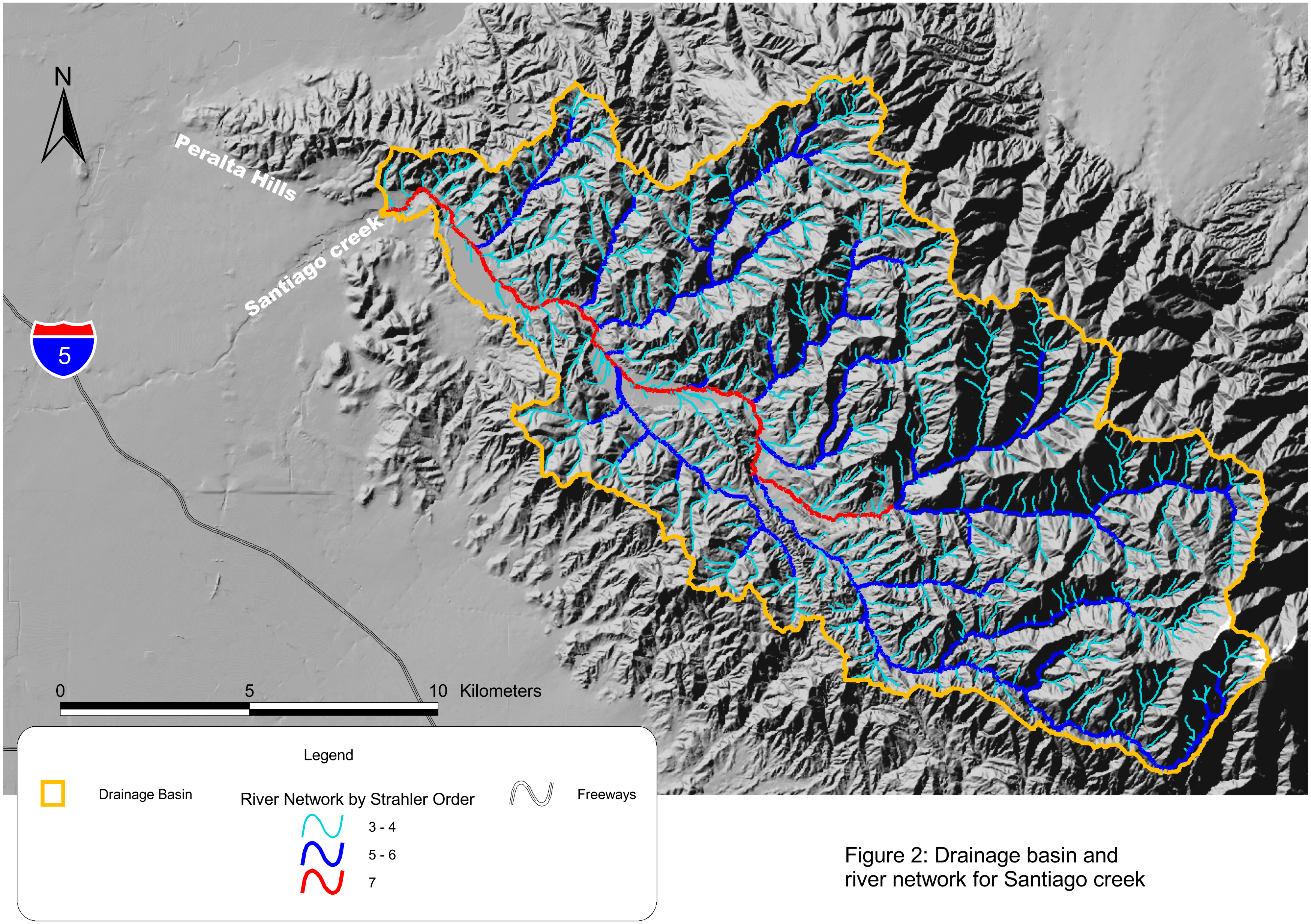

Figure 2: Drainage basin and
river network for Santiago creek

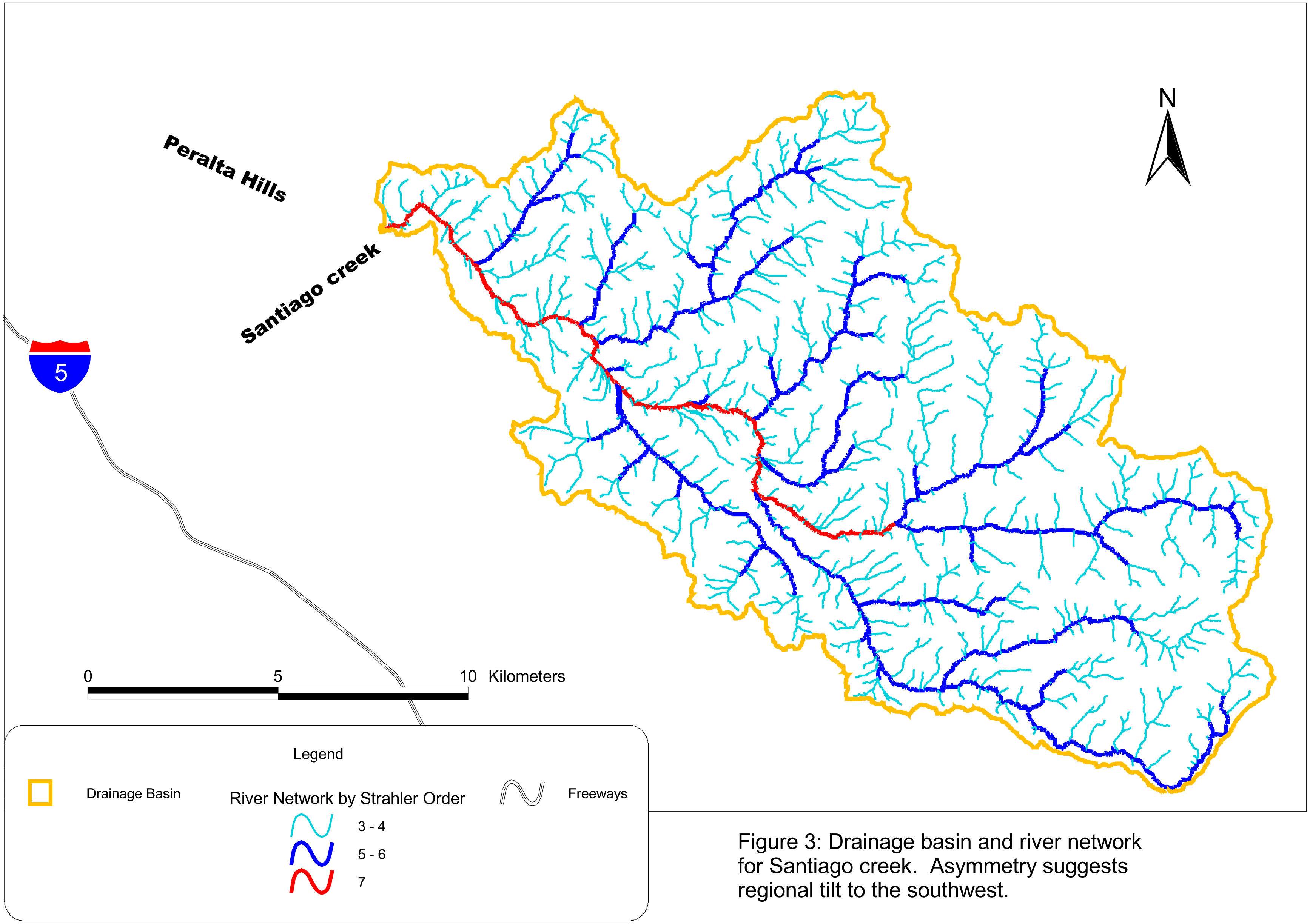

Figure 3: Drainage basin and river network for Santiago creek. Asymmetry suggests regional tilt to the southwest.

Active Deformation and Earthquake Potential of the Southern Los Angeles Basin, Orange County, California

External Grant Award No. 01HQGR0117

Lisa B. Grant, P.I., with Eric E. Runnerstrom and Eldon M. Gath
Dept. Environmental Analysis & Design, University of California, Irvine, CA 92697-7070;
phone (949) 824-5491 fax (949) 824-2056 email lgrant@uci.edu

NEHRP Element: III
Keywords: Tectonic geomorphology, Tectonic structures, Regional modeling,
Surface deformation

Non-technical summary
The Santa Ana Mountains are prominent features in the landscape of the metropolitan Los Angeles basin. Comparable sized mountains and foothills in surrounding areas are known to be associated with active faults or folds. This project investigates possible tectonic deformation and earthquake potential associated with undiscovered faults in or near the Santa Ana Mountains by examining the patterns carved by streams. Preliminary results suggest that the mountains are rising and may contain active faults.